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THE BARNESMORE COMPLEX, COUNTY DONEGAL

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PLATE 14.

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(PLATE 14).

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I. INTRODUCTION.

The Barnesmore Granite Complex forms twenty square miles of rugged and uninhabited country in County Donegal in the north-west of Ireland. The age of the granites, which are intruded into Dalradian schists, has hitherto been in doubt; several lines of evidence appeared to favour a Tertiary age, others a

Caledonian, and it was mainly to throw further light upon the age of the granites that the writers commenced a restudy of the area in the summer of 1949. The scope of the work widened when it was found that the Barnesmore mass consists not of one granite but of several distinct intrusions, and in 1949 and the following summer the whole area was remapped on the six-inch scale.

(*a*) *Previous work.*

In 1887 S. H. Haughton described pitchstone dykes cutting the granites, and published a chemical analysis of one, the only analysis available when the present work was commenced. E. W. Egan, J. R. Kilroe and W. F. Mitchell of the Geological Survey of Ireland mapped the district in which the Complex lies during the years 1881-85, and a map on the scale of one inch to the mile accompanied by an explanatory Memoir was published in 1888. They recognized that the granite mass, the outlines of which they traced accurately, was a discordant intrusive body irrupted into the schists, but did not suspect its composite nature.

W. J. Sollas published an account of some Tertiary pitchstone and andesite dykes in 1893, and H. J. Seymour briefly described the microscopic characters of the Barnesmore granite in 1908 in connection with the source of granite boulders in the drift of the Londonderry district, but no other petrographic work appears to have been done on the rocks of the Complex. The glacial geology has been studied by J. K. Charlesworth (1924). Apart from very brief mention in a number of works, the only other reference to the geology of the Barnesmore area appears to be that by W. R. Flett (1938).

Professor A. Holmes recently commenced an examination of the area, but on learning of our intention to investigate it very generously abandoned his studies in our favour.

(*b*) *Topography.*

The Barnesmore Complex forms a rather isolated tract of high ground in the south of Donegal, rising to above 2,000 feet in the Blue Stack mountains in the west. The granite range is intersected by several deep valleys with north-easterly trend, of which one, the Barnesmore Gap, is well known, followed as it is by a railway and main road. The remainder of the Barnesmore range is trackless. Although not particularly elevated the granite country is quite rugged, and as more than fifty per cent. of the ground is bare rock it ranks as one of the best-exposed granite masses in the British Isles. In a few areas, however, exposures are lacking. Particularly is this so along the northern and eastern margins of the Complex where there are considerable spreads of drift and bog, and the main valleys contain a good deal of scree and alluvium. With these exceptions, however, bare, glaciated rock surfaces with small pockets of bog are the rule.

J. K. Charlesworth has shown that the Donegal mountains were the centre of a large ice-sheet during the Ice Age, and the excellence of exposures in the Barnesmore area is directly due to the glaciation. To quote Charlesworth (1924, p. 199), "The Blue Stack and Barnesmore granite hills . . . exhibit smooth moutonnée

summits, beautifully rounded shoulders, and steep glaciated ridges which descend sharply into broad U-valleys." Most of the small lakes which are so plentiful in the schist country south of the granite are rock-basin lakes, and Lough Belshade is the product of a corrie-glacier.

II. COUNTRY ROCKS.

The Barnesmore granites have been intruded into a series of crystalline schists of Dalradian age. The regional strike is very constant, and lies between W. and W.N.W., and the dip is almost invariably towards the N. or N.N.E. at angles ranging from 20° to 80°, and averaging 40°, rising to 45-80° immediately adjacent to the granite. Determination of the stratigraphy and structure of the schists was beyond the scope of the present work, but the rocks are probably part of the northern limb of Anderson's (1948) Lough Derg anticline. The constant dip and strike found in the vicinity of the Complex persists to a distance of about ten miles to the west, when it suddenly changes across a prominent fracture zone and becomes NE-SW.

The most abundant rock type is a semi-pelitic or quartzose mica-schist with good planar schistosity, consisting of roughly equal amounts of muscovite, and biotite, abundant quartz, and a little plagioclase feldspar. By increase in quartz the rocks grade into granulites, such as are developed in the Owendoo valley. No true quartzites appear in the immediate vicinity of the Complex but they have been mapped further north and south by the Geological Survey, and the same is true of limestones and calc-schists. Pelitic schists, although rather subordinate in amount, are widespread as distinct bands a foot or so thick, mainly interbedded with the semi-pelitic schists, and consist of roughly equal amounts of biotite, muscovite, oligoclase, and quartz. Bands of pink, feldspathic schist composed mainly of oligoclase and muscovite with subordinate quartz and biotite are developed near Benson's Hill.

The Dalradian schists contain numerous bands of hornblende-schist and amphibolite, which probably represent basic sills intruded before the regional metamorphism. The former seldom exceed a few feet in thickness, and always show good linear schistosity. They consist of hornblende, medium plagioclase, and a little quartz, with accessory magnetite and sphene. True amphibolites have been found only as several thick sheets near Clogher Hill, locally showing conspicuous epidotization.

The schists in the vicinity of the Barnesmore Complex lie within the biotite zone of regional metamorphism, and garnet has not been observed in any of the rocks. The metamorphic grade increases towards the south-east where, in the Lough Derg area (Anderson, 1948), garnet and kyanite are developed and are related to the regional injection.

At a number of points near the margin of the granite the schists have been permeated by pink feldspathic material, mainly microcline, accompanied by quartz. Sillimanite is occasionally developed, as felts of small needles, and the granite

intrusion was clearly responsible for its formation. In the more pelitic bands andalusite is typically developed to a short distance from the granite margin, and the crystals, which are commonly an inch or more in length, are conspicuous on weathered surfaces.

III. Plutonic Rocks.

The Barnesmore Complex is made up of several distinct intrusions of granite of slightly different age, separated by sharp and sometimes chilled contacts. They are, in the order of intrusion :

G1. The Cronamuck granodiorite.—Believed to be the earliest igneous rock exposed, distinguished from G2 by its finer grain and porphyritic nature, and from G2 and G3 by its relative richness in biotite. It is certainly earlier than G3, numerous sheets of which intersect it, and it probably preceded G2.

G2. The main granite.—A coarse-grained, typically non-porphyritic and highly leucocratic pink granite or adamellite, constituting more than half of the Complex and therefore regarded as the normal granite.

G3. The sheet complex.—Shows a marked tendency to occur as sheets intruded into G1 and G2, against which it everywhere presents sharp contacts. The rocks are very heterogeneous, but two main types can be distinguished :

a. Even-grained aplogranite or granite, very leucocratic, and typically finer in grain than G2, but the more granitic varieties are sometimes rather hard to distinguish in the field from G2.

b. Porphyritic aplogranite, characterized by the presence of phenocrysts of feldspar and quartz in varying amounts in an aplogranite groundmass.

(*a*) *Field characters.*

It is always possible, though at times difficult, to distinguish between the constituent granitic rocks of the Barnesmore Complex. As it is not always possible to identify the rocks with certainty on weathered surfaces, mapping of the contacts is a long and tedious task. The sugar-grained aplogranite characteristic of G3*a* is, however, quite distinctive on weathered surfaces, and typical G1 weathers to a rather deeper colour than the other granitic rocks. One very useful feature shown by the sheet complex as a whole is its heterogeneity and the abundance of pegmatite layers through much of its mass ; G2 on the other hand is remarkably uniform in composition and grain-size over wide areas.

Another feature which renders mapping of the constituent plutonic rocks and interpretation of their structure difficult is the apparent absence of any relationship between the topography and the structure. It is true that the rocks of the sheet complex form the highest ground, but this is unlikely to be due to superior resistance

to weathering, and no examples have been found in which the internal contacts are marked by topographical features, however slight.

On the accompanying map of the Barnesmore Complex, Plate 14, the above four rocks have been delimited, and the inclination of the internal and external contacts plotted where determined. Many sheets of G3 have been omitted, intentionally or otherwise, but it is believed that the distribution of the sheet complex as a whole as indicated on the map is tolerably accurate and complete.

The Cronamuck granodiorite, G1, is practically confined to a small area, enclosed mainly by G3, in the centre of the Barnesmore Complex, but there is also a small area of a rock similar to G1 enclosed in the main granite on the north-west shoulder of Glascarns Hill. Small xenoliths of granodiorite are seen in the stream running into Croaghanard Lough from the south-west and one, five feet in diameter, was found near the margin of the Complex practically at its south-western extremity. In the Cronamuck area the most basic and fine-grained variety of G1 appears just below the aplogranite capping it on the ridge north of Croaghanirwore, which rather suggests that the granodiorite here is not far from its original roof.

The granodiorite typical of G1 is quite distinct from G2, but the rock-mass is very heterogeneous and in places is only slightly more basic than the main granite, which rather suggests that G1 represents a basic facies of G2. However, sharp contacts between the two are found at several points in the Cronamuck area, and in the xenoliths in the west and north of the Complex. If these xenoliths are derived from G1, and their petrographic character is strongly in favour of this supposition, G1 must have antedated the main granite, and therefore represents the earliest rock in the Barnesmore Complex.

(*b*) *Petrography.*

All the plutonic rocks are composed of sodic plagioclase, potash feldspar, quartz, biotite, and muscovite, in varying amounts, and other minerals are seldom present in more than traces. The plagioclase is as basic as An 30 in the granodiorite, but in the more acid rocks it is albite. The crystals are usually zoned, with cores more basic than the margins. The potash feldspar nearly always contains perthitic laminae, and sometimes shows cross-hatched twinning of microcline type. The feldspar is frequently bent or fractured, and the quartz crystals almost invariably exhibit strain shadows under crossed nicols ; these effects are not surprising in view of the subsequent tectonic history of the Complex.

Biotite is the only ferromagnesian mineral, and, except in the granodiorite, ranks as little more than an accessory mineral. Alteration to an intergrowth of chlorite and muscovite is very common, and at other times the biotite has altered to chlorite with separation of iron ore. Separate flakes of muscovite are common, sometimes clearly secondary after plagioclase feldspar. The potash feldspar and the more basic cores of the plagioclase are often turbid through alteration, and they are iron-stained, this being responsible for the pink colour which is so characteristic a feature of all the Barnesmore granitic rocks.

(i). *The Cronamuck granodiorite.*—The granodiorite is typically a medium to fine-grained biotite-granodiorite with rather sparse phenocrysts of quartz and plagioclase. The dominant mineral in the groundmass is oligoclase in subhedral crystals zoned from cores of An 30 to margins of An 14. The more basic plagioclase is usually somewhat sericitized. Potash feldspar is subordinate in amount and is interstitial to the other minerals. There is also brown biotite, and accessory iron ore, allanite, sphene, and apatite.

The granodiorite varies considerably in composition and grain-size, and in places differs but little from the main granite. A chemical analysis of one of the most basic varieties of the granodiorite, B. 249, from below the aplogranite cap on the ridge north of Croaghanirwore, is given in Table I, together with a mode determined by linear measurement of several thin sections, and expressed in terms of volume percentages. The relatively high content of potash in the analysis is rather unexpected, but a granodiorite with analysis and mode closely similar to those of the Barnesmore rock, except in being less silicic, has been recorded from the Criffel mass by M. MacGregor (1937). Of British Caledonian granodiorites, however, the fine-grained granodiorite described by S. R. Nockolds (1940) from Garabal Hill compares most closely with the Barnesmore rock, although even here the latter is rather unusual in its high content of silica.

(ii). *The main granite.*—G2 is a pink, coarse-grained and very leucocratic granitic rock corresponding in composition to an adamellite. Apart from marginal basification to a few feet from the contact with the Dalradian schists the main granite is remarkably uniform throughout the Complex, and the uniformity evident in the field is fully borne out by microscopic study. To the N.W. and S.E. the granite is slightly richer in quartz than at the centre of the Complex, but the difference is not great. In only one place, near the western extremity of the Complex, has a slight flow-banding been seen ; elsewhere directional structures appear to be absent.

TABLE I.

Chemical analyses and modes (vol. per cent.) of granitic rocks from the Barnesmore Complex. Analyst W. H. Herdsman.

B. 249.—Granodiorite, G1, fine-grained variety, below aplogranite cap on ridge running N.E. from Croaghanirwore.

B.258.—Granite, G2, half a mile west of Croaghanirwore.

G.2.—Calculated analysis of quartz-rich variety of G2.

	B.249	B.258	G.2
SiO_2	71·06	75·73	80·2
TiO_2	0·18	0·12	
Al_2O_3	15·28	13·56	11·2

Fe_2O_3	0·40	0·22		
FeO	1·89	1·35		
MnO	0·05	tr.	·9	
MgO	0·92	0·42		
CaO	1·76	1·03	0·8	
Na_2O	4·32	3·28	3·3	
K_2O	3·12	4·06	3·6	
P_2O_5	0·06	0·12		
H_2O^+	0·63	0·28		
H_2O^-	0·09	0·04		
Total ...	99·76	100·21		G3a.

MODES.				
quartz	25	31	46	30
K feldspar ...	15	30	25	28
plagioclase ...	55	37	27	40
rest (mainly biotite)	5	2	2	2

As seen in hand specimens the rock is non-porphyritic and consists of a coarse-grained aggregate of pink feldspar and quartz, the latter showing a distinct tendency to segregate into patches 5 mm. or more in diameter. Phenocrysts of feldspar are extremely rare, but have been seen in a few places, and the same applies to xenoliths, although a few of granodiorite similar to G1 and, north of Lough Belshade, a single xenolith a few inches in diameter of schist were found.

Potash feldspar and plagioclase are present in approximately equal amount. The former is a microcline-microperthite forming rather large, partly interstitial, crystals. The plagioclase crystals, which are smaller, tend to be idiomorphic. A core of oligoclase passes outwards to a marginal zone of almost pure albite, and outgrowths of myrmekite into the potash feldspar are quite common. The biotite is seldom fresh. Inclusions are sometimes enclosed by a pleochroic halo.

A chemical analysis of a specimen of granite (B. 258) from the western slopes of Croaghanirwore is given, together with a mode, in Table 1, and a calculated analysis of a more siliceous variety of G2 is included. Analyses of Scottish Caledonian granites do not correspond very closely owing to the highly siliceous nature of G2, but analyses of the Moy (Nockolds & Mitchell, 1948) and Meall Odhar (J. G. S. Anderson, 1937) granites agree quite well. Although available petrographic and chemical data are inadequate, it seems probable that the main granite of the Barnesmore Complex finds its closest parallel in Scotland with the granites of the central and eastern Grampians.

(iii). *The sheet complex.*—The non-porphyritic type, G3*a*, occupies a large area in the middle of the Barnesmore Complex. It is a pink aplogranite grading into granite, and in most places an aplitic facies is developed towards the margins. Examination of thin sections under the microscope reveals that the rocks are very

constant in composition. The plagioclase feldspar is very sodic, with composition about An 8, and only slight zoning is developed. The potash feldspar is more turbid than the plagioclase, and the crystals are usually badly strained, and with poorly developed cross-hatched twinning. Perthitic laminae, when present, are always small. A mode, the average of that of a number of thin sections, is given in Table I. Chemically G3*a* can differ only slightly from B.258, the analysed specimen of the main granite.

The texture of G3*a* is allotriomorphic and even-grained, although there is a tendency for the individuals of plagioclase to be rather larger than those of quartz and potash feldspar. G3*b* differs from G3*a* in its porphyritic character, the phenocrysts, which are in variable amount and usually less than 5 mm. in diameter, being of oligoclase, strongly zoned on the margins to albite, perthitic potash feldspar, quartz, and sometimes biotite.

(*c*) *Pegmatites, aplites and quartz veins.*

Veins and dykes of aplite are very common in the Barnesmore Complex, particularly in the vicinity of the margins of the sheet complex, indicating very close genetic relations between the two. The thickness of individual veins is usually of the order of an inch or two, but larger veins are common, and dykes of aplite or aplogranite up to 30 feet wide have been met with. The veins and dykes are mostly steeply inclined, and, although in places a plexus of aplites is found, the veins more commonly fall into one or two well-marked sets.

Pegmatites are also common throughout the greater part of the Complex. They consist mainly of a coarse-grained aggregate of pink potash feldspar and milky quartz, the latter particularly towards the middle, with grain-size commonly of several inches. Graphic intergrowths are often found, usually towards the margin of the pegmatite. Sometimes there is a little mica, and crystals of ilmenite occur in a two-foot sheet of pegmatite at the top of the col between the Blue Stack and Lough Aduff Hill; otherwise the pegmatites are remarkably uniform and monotonous in composition. Those found in the main granite are often in large irregular masses up to ten feet or more in diameter, but distinct veins, sheets and dykes, usually partly aplitic, are also found. Layers of pegmatitic granite are common throughout much of the sheet complex.

Quartz veins are common and belong to three clearly-marked groups. There are, firstly, the early hydrothermal quartz veins, particularly abundant around Lough Belshade, steeply inclined and often regular over considerable distances. The thickness is normally less than one inch, and the quartz never shows comby structure. These veins post-date the aplites and pegmatites but probably follow them closely. Secondly, in a few places there are networks of veins of milky quartz, sometimes associated with large pipe-like masses of quartz, that do not appear to be related to fracture lines in the granite; instead they seem to be related genetically to the dykes of the Caledonian swarm. Finally, there are the later comby quartz veins, often amethystine, and rather irregular in form, which are closely related to the faulting of the granite. Such veins are often seen to displace aplites. In a few places intense silicification of the fractured granite in or near faults is found.

IV. STRUCTURAL RELATIONS OF THE GRANITES.

(*a*) *Outer margins of the Complex.*

The granites of the Barnesmore Complex everwhere exhibit a sharp and discordant contact against the Dalradian schists. Veining of the schists near the contact is usually present, but is rarely well developed. Xenoliths within the granite are extremely rare. The contact is readily mapped, and for the most part was traced accurately by the Geological Survey. The contact is well exposed except locally along the north and east, where it may be concealed by drift and bog.

In many places it has been found possible to measure the inclination of the contact plane, and the average dip of fifty determinations is 50° outwards. In only a few places is the contact vertical, and it is never inclined inwards. Often the outwards inclination is small; the large remnant of schist on Pollakeeran Hill represents a gently-inclined portion of the roof of the Complex, and other roof remnants are met with just north of Illanmore Lough, in the south-west near Lough Nacollum, and in the west near Lough Nacroagh. The outcrop of the contact across Clogher Hill, the ridge of Croaghgorm, and the south-west shoulder of Croaghconnellagh is clearly indicative of a rather gentle outward inclination of the contact plane. On the Croaghgorm ridge the contact steepens at lower levels.

We conclude that the Complex has the form of a dome, elongated N.W.-S.E. and nearly everywhere markedly discordant to the country rocks. Little evidence of shouldering-aside of the schists can be discerned, and the rarity of xenoliths is contrary to the idea of piecemeal stoping as having made way for the granite. The slight marginal basification of the granite that extends to a few feet from the contact may be the result of incorporation of some of the country rock, but it is unlikely that this process has operated on a large scale. We believe that the Complex came into being as a consequence of the subsidence of a large block of schists, perhaps along a ring-dyke type of fracture, the ring-dyke itself being below the present level of erosion, in the manner postulated by Richey (1926) for the Mourne Mountains granite mass. As in the Mournes, however, direct evidence for the existence of a floor to the Complex has not been found. Indirect evidence of a floor of schist is supplied by the breccia-vents which cut the granite and are described in a later section. Examples of subterranean cauldron subsidence of type similar to that postulated here and in which subsidence of the floor has been proved have been described by J. Ellis (1940 and 1944) from the Karroo of the Transvaal.

(*b*) *The sheet complex.*

Though very variable the rocks of the sheet complex are divisible into two types, namely a porphyritic aplogranite and an even-grained aplogranite or granite, and on the map, Plate 14, an attempt has been made to distinguish between the areas occupied by these two types. On the top of Croaghconnellagh they come into contact, and at one point 400 yards north-west of the summit a few small xenoliths of the even-grained type were found enclosed in the porphyritic. It seems likely, however, that although the porphyritic type is thus indicated as the later,

there is only a very slight age difference. In any case, it is not certain that either type is everywhere of the same age, and, indeed, the heterogeneity of the sheet complex as a whole strongly suggests that it represents successive injections of magma. One fact, however, is certain, namely that the sheet complex is later than the main granite and the Cronamuck granodiorite.

In its structural relations the sheet complex shows some very remarkable features. In general two structural components can be distinguished, namely an outer discontinuous ring, mainly of the porphyritic type, closely following and usually coincident with the outer margins of the Complex, and an inner mass, mainly of the even-grained type, itself partly in the form of a ring.

(i) *The inner component.*—This constitutes in the south a large mass on Croaghconnellagh and Croaghnageer, in the form of a very thick sheet inclined at about 60° towards the north-east. This inclination is well seen in the manner in which the eastern outcrop crosses two ridges on the north-east shoulder of Croaghconnellagh. On one of these ridges and again on Brown's Hill the main mass gives off towards the north-east a number of sheets which dip gently and die out laterally in the same direction. The other margin of the Croaghconnellagh-Croaghnageer mass is inclined steeply towards the north-east, but on the tops of the two hills curves over to form a roof to the main granite. This roof has been largely eroded from Croaghnageer, although on the summit of this hill and on Croaghanirwore a number of horizontal sheets issue from the main mass of aplogranite to the east. Combined with the large mass of porphyritic aplogranite, which is inclined as a sheet at 50° towards the south-west, on the western shoulders of these hills, the sheet complex forms what might be termed an *igneous arch*, and which it is proposed to call the Croaghconnellagh igneous arch. The axis of this arch, which in form resembles an anticline but which has not been formed as a result of folding, runs through the summits of Croaghanirwore, Croaghnageer West, Croaghconnellagh, and, if the small patches of aplogranite there are to be regarded as roof remnants, Barnesmore or Croaghconagh.

North of Croaghnageer the inner structural component of the sheet complex undergoes a change, forming a dome or second igneous arch, the Cronamuck arch, with the earlier granite and granodiorite of the core exposed by erosion in the Cronamuck valley and neighbouring hills. This core, much broken up by aplogranite sheets, is roofed by nearly horizontal aplogranite on the ridge north of Croaghanirwore, and probably also on Meenanea, but elsewhere appears to be bounded by contacts inclined steeply outwards. The outer margin of this mass of aplogranite is inclined at a moderate angle outwards, and at two places, namely on the Croaghbarnes ridge and on the steep northern face of Cronamuck Hill, gives off a number of sheets with smaller outward inclination than the main mass of aplogranite. The relationships are particularly well seen at the latter place, where part of a large mass of aplogranite forming the top of the hill is seen to finger out downwards. In view of the approximate coincidence between the dip of these sheets and the topographic slope it is not possible to represent this fingering adequately on a map. The screen of main granite shown near the top of the hill is probably related to the fingering seen further north, and may represent a tongue joining the main mass of granite below the hill.

North of the Lough Belshade fault the place of the inner component of the sheet complex is taken by a series of sheets with semi-circular outcrops concentric about Lough Belshade and inclined outwards at an average angle of 35° to 40°. In the vicinity of Lough Aduff there are two sheets which may be traced laterally for more than a mile ; beyond that no attempt has been made to map individual sheets, and the fingering-out of one of the sheets on Binmore shown on the map, Plate 14, is schematic. The marked northwards bulge of the upper Lough Aduff sheet in the upper part of the Effernagh valley is due to the approximate coincidence between the dip of the sheet and the topographic slope, and the wide outcrop of an isolated sheet south of Croaghanard Lough is due to the same effect.

The large mass of aplogranite on the hill south of Lough Aduff appears to finger off into a number of sheets eastwards. It is not certain whether this fingering takes place laterally or in depth, but if, as is believed, the latter is the case it would suggest that the sheets north of the Lough Belshade fault issue from a larger mass, now eroded away, above Lough Belshade, and finger and thin downwards. Inspection of the measured dips of the sheets at different distances from Lough Belshade reveals a general outward decrease, clearly indicating downward divergence of the sheets and providing further evidence for the former existence of this larger, parent body above the present site of Lough Belshade.

The Lough Belshade fracture is unquestionably a tear fault with large lateral displacement, but a glance at the map, Plate 14, shows that the structures in the sheet complex on either side of the fault do not match. In the absence of a normal element in the fault displacement the aplogranite of the northward-pitching nose of the Cronamuck arch would come to lie below Lough Belshade, and the sheets of the L. Aduff-Binmore system would be unrelated to the aplogranite of the Cronamuch arch, although coaxial with it. Alternatively a fit can be effected by adding a downthrow to the south-east of the order of 2,000 feet to the Lough Belshade fault, which is not unreasonable when it is remembered that there is a known lateral displacement of 11,500 feet ; in any case there is a proved downthrow in this direction south-west of the Complex where the fault traverses the Carboniferous. Allowing for this downthrow, the aplogranite mass of the Cronamuck arch comes to lie above the present position of Lough Belshade, and can, indeed, be regarded as the source of the sheets of the L. Aduff-Binmore system.

(ii) *The outer component.*—The largest mass of porphyritic aplogranite forms a thick sheet inclined south-west at about 50° and stretching from the southern entrance to the Barnesmore Gap to near Lough Illanmore. Near the top of Croaghconnellagh it curves over to meet the evengrained aplogranite of the inner component with which it forms the roof of the Croaghconnellagh igneous arch. Half a mile north of Barnes River the mass thins abruptly and splits into several sheets, as represented on the detailed map, fig. 1. One sheet follows the granite-schist contact, and the widening of its outcrop north of Illanmore Lough is due to its low dip on the shoulder of Croaghanirwore, which it partly roofs. In the valley west of that hill the marginal sheet splits and becomes very irregular, and one branch can be traced as a discontinuous sheet, inclined outwards at a low angle, to near the top of

Croaghbarnes. This sheet has probably been given off from the mass of aplogranite constituting the Cronamuck arch.

At the southern entrance to the Barnesmore Gap the large mass of porphyritic aplogranite forming half of the Croaghconnellagh arch thins out very abruptly, and gives the impression of wedging-off downwards. South-east of the Gap the porphyritic aplogranite outcrops in an almost continuous strip, sometimes as narrow as ten yards, between the main granite and the schist. It is quite likely that this marginal sheet continues as far as the eastern end of the Gap, but the exposures here are very poor. On Croaghbrack and Clogher Hill sheets of aplogranite appear at or near to the schist contact, the aplogranite composing them being non-porphyritic. A group of sheets have been mapped between Clogher Hill and the Cronamuck River, but their form is uncertain owing to the paucity of exposures. Other small exposures of aplogranite have been found in the vicinity, but as their shape is unknown they have not been indicated on the map, Plate 14.

North of the Lough Belshade fault an aplogranite rich in large phenocrysts is met with in the vicinity of Croaghanard Lough and again in the Effernagh River along the granite-schist contact, and a similar sheet of small lateral extent appears on the southern slope of Croaghgorm. There is a further sheet of porphyritic aplogranite within the main granite on the ridge north of Glascarns Hill, dipping down the slope.

The most interesting feature shown by the porphyritic aplogranite of the outer ring is the remarkable tendency to follow the contact between the earlier, main granite and the schists. Such a marginal sheet has been met with around at least half of the circumference of the Barnesmore Complex, in some places as a narrow strip only a few yards in width. From its distribution it might be thought to represent a marginal chilled facies to the main granite, and its possession of a sharp contact against the granite could not be cited as unequivocal evidence against this view. In the circumstances it is desirable to consider very carefully the evidence upon which the accepted age relations, that is aplogranite (G3*b*) following the main granite (G2), are based. There is, in the first place, the observation that rocks of the sheet complex throughout the Barnesmore Complex commonly—one might say characteristically—appear as sheets intruded into the main granite, and that the marginal aplogranite sheets are exactly similar in all respects to *bona fide* sheet complex masses with which, indeed, they are often continuous. Chilling, although not conspicuously developed in the sheet complex, has been observed; for example, the aplogranite of the western side of the Cronamuck arch is chilled to a distance of several hundred feet from the contact with the main granite. In several places xenoliths of the main granite have been seen. A detailed study of the contact relations has been made, and at several places direct field evidence of the age relations thereby obtained. Thus a thin aplogranite sheet follows the granite-schist contact for a distance of about 1½ miles in the vicinity of Illanmore Lough (see map, fig. 1), but although following the contact very closely there is a thin and discontinuous layer of G2 in contact with the schist outside the aplogranite sheet. This outer veneer of the main granite is often no more than a few feet or inches wide, and could not be accounted for were the aplogranite an early chilled

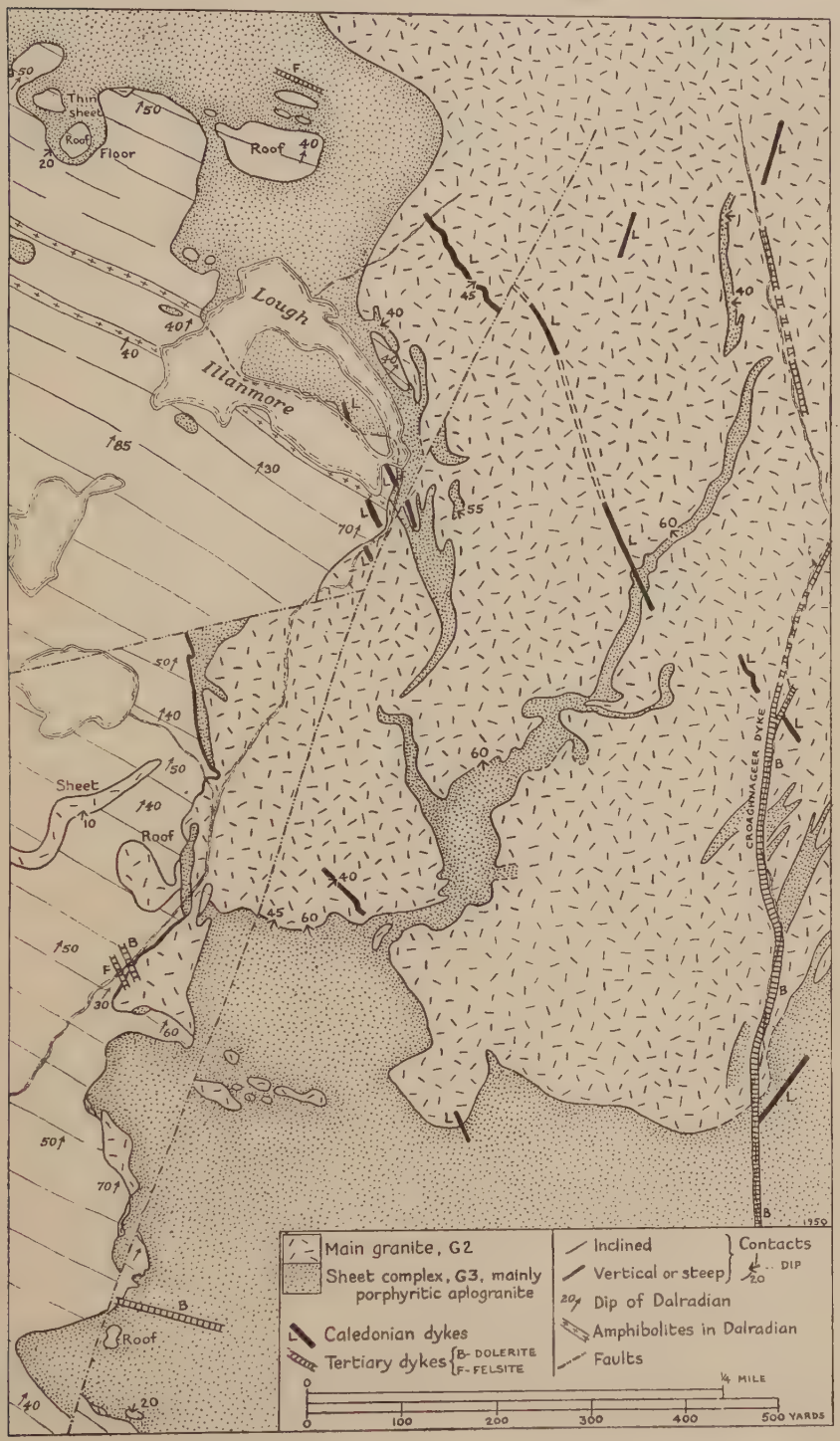

FIG. 1.—Geological map of the Lough Illanmore area.

marginal phase of G2. A similar relationship was found at one point 150 yards west of Lough Napaste, where the aplogranite contains also a few xenoliths of G2. Details of the contact are shown in fig. 2. In only one instance has a thin screen of Dalradian schist been found caught up between the main granite on the inside and an aplogranite sheet on the outside ; this example, a few yards from the north-east shore of Lough Illanmore (fig. 1), offers convincing proof of the later age of the aplogranite.

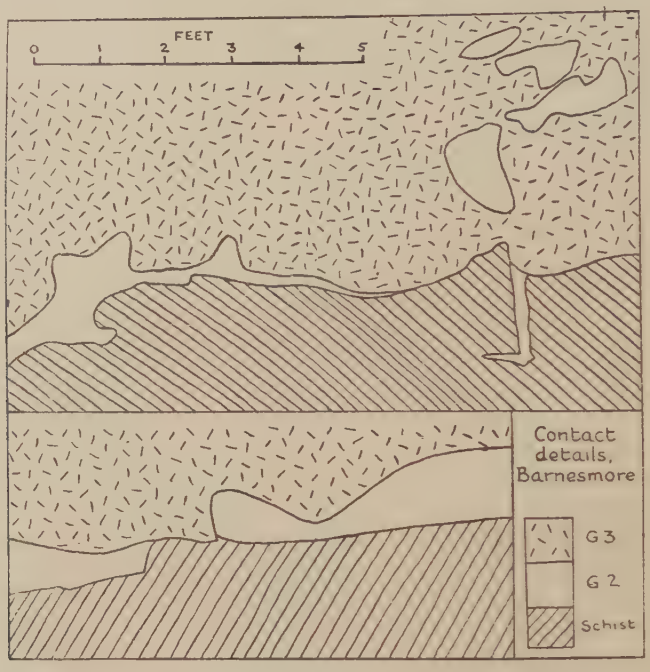

Fig. 2.—Contact details useful for determination of the relative age of G2 and G3. Above: 150 yards east of Lough Napaste. Below: south of Lough Illanmore.

(iii) *Mode of emplacement of the sheet complex.*—To account for the formation of the large mass of aplogranite of the inner ring of the sheet complex we are forced to postulate the subsidence of a block of country rock at the centre of the main granite and bounded roughly by the line Cronamuck Hill-Brown's Hill-Croaghnageer-Croaghanirwore-Croaghbarnes ridge, fig. 3. It is reasonable to suppose that the Cronamuck granodiorite represents an earlier intrusion emplaced above the main granite, and that its preservation in the Cronamuck arch is directly due to this subsidence. In this connection it should be recalled that what may be a chilled marginal phase originally at the roof of the granodiorite is found just below the aplogranite capping it on the ridge north of Croaghanirwore.

The writers believe that the main granite was emplaced as a result of subsidence of a large, dome-topped block of country rock, perhaps representing the top of a ring-dyke type of fracture, and it may be that further sinking of the

central block along the same lines of fracture led to the emplacement of the outer ring of the sheet complex. An alternative explanation, which fits the evidence much better, is that the formation of the outer ring followed subsidence of the block below the Cronamuck arch; the consequent weakening of the supports of the surrounding granite led to a partial caving-in of the latter along fractures such as those represented by the dashed lines of fig. 3. Such fractures, once initiated,

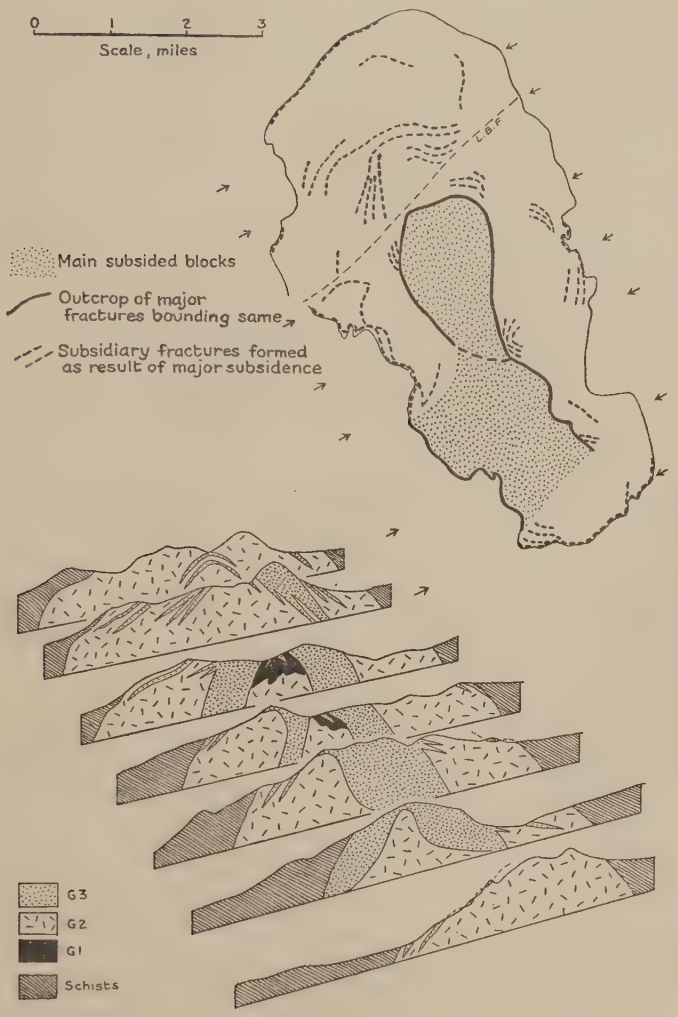

FIG. 3.—Structure of the Barnesmore Complex. Above: structural map. Below: serial sections across the Complex.

would be extended by wedge-action due to the hydrostatic pressure of the aplo-granite magma, with preferential separation along the line of weakness represented by the granite-schist contact. Such an explanation would imply injection of magma outwards and downwards; this is clearly indicated in the case of the fingering sheets on Brown's Hill, on the north face of Cronamuck Hill, and on the Croaghbarnes

ridge, and it has already been suggested that the Lough Aduff-Binmore system of sheets north of the Lough Belshade fault has been derived by injection of magma outwards and downwards from a source above the present site of Lough Belshade, that is, from the nose of the Cronamuck arch. Fig. 4 is a generalised picture of our interpretation of the structural relations of the sheet complex.

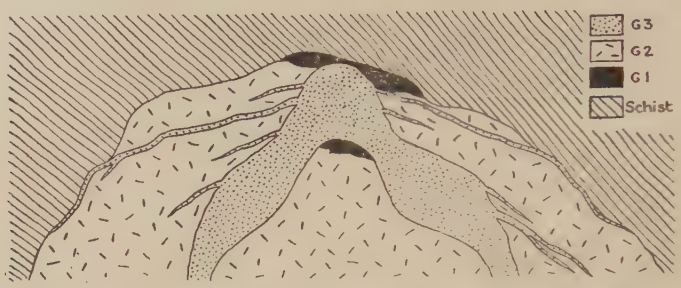

Fig. 4.—Generalised section across the Barnesmore Complex to illustrate the essential features in our structural interpretation of the Complex. The main mass of G3 was emplaced by subsidence of a large block of G1 and G2; the thin sheets of G3 were intruded along fractures resulting from partial caving-in at the unsupported sides of the main subsided area.

Either interpretation of the origin of the outer ring of the sheet complex involves the conception of fracture taking place almost exactly along the contact between G2 and the schists. In view of the different physical properties possessed by these two rocks this seems reasonable. There may also have been a certain amount of corrosion of the granite and schist and incorporation into the aplogranite to account for the general perfection of the separation of granite from schist seen in the field.

The origin of the Croaghconnellagh arch poses a special problem. In our view it is due to the down-sagging of a large mass of G2, with complete separation from the schist, consequent on the foundering of the block below the Cronamuch arch.

V. Deuteric Effects.

(*a*) *Field relations.*

A characteristic feature of the Barnesmore Complex is the presence of small scattered bodies of granite which have suffered deuteric alteration to a syenitic rock. These bodies, which are usually less than 100 feet in diameter, are readily recognized in the field by their deep red colour, their frequently cavernous nature, and by the fact that the rock is free, or almost free, from quartz. Known bodies are plotted on the map, Plate 14. South of the Lough Belshade fault they have been found only at a few places, but north of the fault they are common, and they attain their greatest development in a compact area of about half a mile square on Mullaghnadreesruhan ; the following description refers mainly to this type

area (fig. 5). Although exposures are good in this area, it is probable that more bodies than those indicated are concealed below scree and bog near the Lough Belshade fault.

The most striking feature shown by the altered rocks is the complete or almost complete disappearance of the large quartz grains which constitute up to nearly 50% of the unaltered granite. This disappearance takes place within the space of an inch or two, and very commonly a sharp contact is observed between the quartz-free and quartz-rich rock, so sharp, indeed, as to suggest intrusive relations. That the contacts are not intrusive is, however, decisively proved by a study of their relationship to the sheets of aplogranite and veins of aplite that cut the main granite. The altered bodies traverse all indiscriminately, but the grain-size and texture of the original rock is maintained, and the contacts between the rock types can be traced readily across the bodies. Drawings of three bodies are reproduced in fig. 5a. In A, a section of a body exposed on a steep rock-face, granite with several aplite veins is traversed by a metasomatic body, the sharp aplite-granite contact being preserved, as is also the difference in grain-size of the two rocks. In B part of a thick sheet of aplogranite is in sharp contact with granite, and the contact is readily traceable across the body, which traverses both rocks. The irregular shape of the bodies, with their embayed margins and islands of unaltered rock, is illustrated by these drawings. The bodies have clearly been developed by alteration of normal granitic rocks after the consolidation of the main granite and the injection of sheets of aplogranite and veins of aplite into it, and the sharp contacts are metasomatic rather than intrusive. It is particularly emphasised that these conclusions are based upon field rather than petrographic or chemical studies.

Certain evidence on the age of the deuteric alteration has already been presented. It is known also that it preceded the intrusion of at least part of the Caledonian dyke swarm, for in one instance (C, fig. 5a) a dyke was observed to cross a metasomatic body in an unaltered condition. Further, the bodies appear to bear no relationship to the numerous faults and lines of intense crush which cut the granites of the Complex. Were these fractures in existence at the time of the metasomatism it would be reasonable to expect that the metasomatizing agents would preferentially have followed them. Numerous quartz veins probably related to the faulting cut indiscriminately through the granite and altered bodies. The metasomatic area on Mullaghnadreesruhan appears to be cut off sharply by the Lough Belshade fault. It is tentatively suggested that the non-appearance of metasomatic bodies on the other side of the fault in the Owendoo valley may be due to the presence of a downthrow to the south-east along the fault in addition to the large lateral displacement.

It is not certain what has caused the localization of the metasomatism. Whilst many bodies are elongated in one direction they show no obvious relationship to the jointing, with the exception of one small body developed along a joint south of Croaghgorm. The granite in the Mullaghnadreesruhan area is more strongly fractured than elsewhere, but it is not certain that there is any close genetic relationship between the fracturing and the metasomatism, for the fracturing may be later, and some of it certainly is. However the metasomatizing solutions no doubt rose

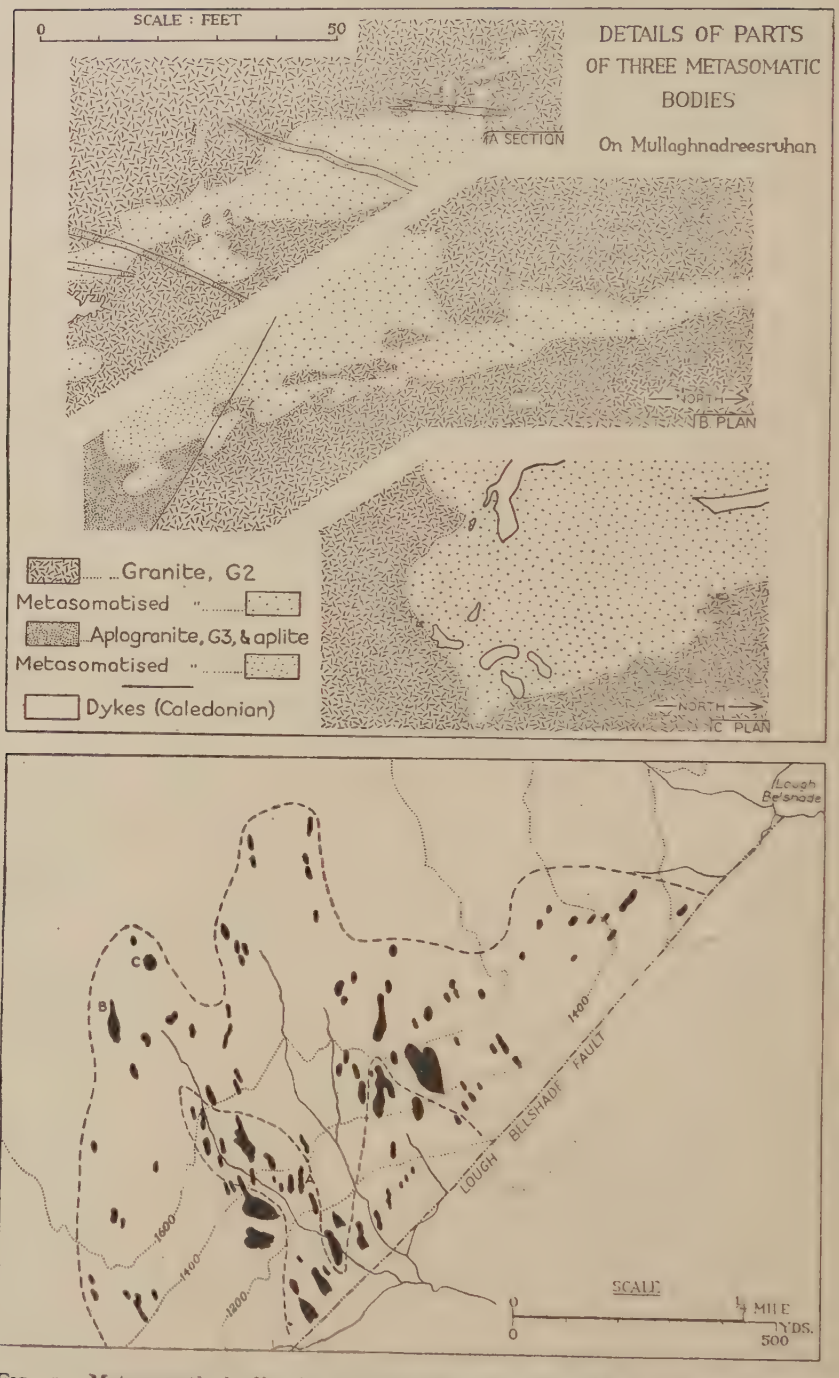

FIG. 5.—Metasomatic bodies in the Mullaghnadreesruhan area. Above: details of three typical bodies. Below: map of their distribution. Those within the inner dashed line are non-cavernous; those outside are cavernous.

through lines of weakness of some sort in the granite. The localization of intense metasomatic alteration into more or less separate, sharply defined, bodies rather than being spread over one large area, although not easy to explain, has its counterpart in the metasomatic bodies so commonly developed in limestone throughout the world.

The Mullaghnadreesruhan bodies occur within a compact area, and a line has been drawn on the map, fig. 5b, to show their approximate limit. A rough zonal arrangement of the bodies may be recognized, with a central core in which the bodies are of compact, non-cavernous rock, and an outer zone in which the rock comprising the bodies is riddled with cavities. These latter rocks are composed of up to 50% of cavities, representing the spaces left by removal of the quartz. Although no carbonate has been found in the cavities it is likely, on analogy with the Cluanie intrusion (Leedal, 1951), that the quartz was first replaced by carbonate, which later became leached out. The line of division between the two types of body is included on the map, fig. 5b, but it must be emphasized that this distinction is very rough. The three-dimensional shape of the metasomatic zones on Mullaghnadreesruhan cannot be determined, but the width of the outer, cavernous zone south-west of Lough Belshade suggests that the upper contact of the metasomatic area dips at a moderate angle towards the Lough. Apart from this one can say only that the shape of the outcrop of the metasomatic area is not inconsistent with its being in the form of a dome truncated abruptly on one side by the Lough Belshade fault. The outcrop of individual bodies is often elongated N.W.–S.E., but in several cases they are sheet-like in form with a low dip towards the south (as fig. 5a, C).

(*b*) *Petrography.*

(i). *Syenitic rocks.*—In thin section the most striking feature shown by the metasomatized rocks is the complete absence of primary quartz; such little quartz as is present is clearly secondary. The rocks consist of feldspar, both albite and potash feldspar being present in much the same proportion as in the normal granite, together with a little chlorite and ore, and sometimes quartz. The potash feldspar, and to a lesser extent the plagioclase, is turbid and iron-stained, this being responsible for the red colour of the rocks. The plagioclase, and in particular its basic core, is sometimes sericitized. The metasomatic rocks which have been sectioned are all badly crushed, but the full significance of this crushing is uncertain.

Microscopic evidence of post-consolidation readjustment in the metasomatized rocks is less striking than might be expected, for the primary quartz has completely vanished without leaving a clue as to the manner of its disappearance, and it can only be assumed that the feldspar crystals enlarged themselves at the expense of the quartz.

There is, however, a good deal of evidence of readjustment within the feldspars, one being replaced by the other. The potash feldspar in the normal granitic rocks of the Barnesmore Complex is usually perthitic, and two types of perthitic laminae may be distinguished, commonly within the same crystal. The most common type, probably of exsolution origin, consists of narrow laminae, very regular in form and orientation, forming one or two sets and normally absent from an outer zone of the potash feldspar crystals. The second type consists of laminae of albite, often more or less spindle-shaped but sometimes highly irregular in shape, which show the same optical orientation over a large area but which do not have constant trend throughout the host crystal. This second type, which is regarded as of replacement origin, increases greatly in amount in the metasomatized rocks, and when the two feldspars are in more or less equal amount it is better described as a mottling of the potash feldspar by albite. Evidence of replacement origin consists in the highly irregular form of the albite lamellae or patches, in their

irregular distribution through the host crystal, in their commonly cutting across the boundaries between adjacent crystals of potash feldspar, and in their often constituting 50% or more of the host crystal.

In a few cases strings of small albite crystals have been observed cutting through potash feldspar crystals or arranged along the inter-grain boundaries and projecting into and replacing the potash feldspar. However it must not be thought that albite always shows replacement relations towards potash feldspar, for the reverse is sometimes found.

In the metasomatized rocks fresh biotite is never seen, and its place is taken by iron ore and chlorite, which do not perfectly reproduce the outlines of the original biotite but form rounded aggregates and strings. Groups of very small vermicular prisms of migratory chlorite are sometimes found, particularly in association with secondary quartz.

(ii). *Silicified rocks.*—Such quartz as does appear in the metasomatized granite is for the most part secondary, and such secondary quartz is particularly abundant in the rocks margining metasomatic bodies, as if the expelled quartz lodged there. Its secondary nature is well established by the virtual absence of the strain shadows invariably present in the primary quartz of the Barnesmore granites, by its poikilitic nature, by the fact that very commonly the crystals appear as radiating groups, and by the frequent presence of distinct veinlets cutting across crystals of feldspar. In the hand specimen minute, well-formed crystals of quartz are sometimes seen investing cavities in the cavernous rocks. Numerous fractures filled with comby quartz cut the granites and metasomatized rocks of the Mullaghnadreesruhan area, and it is likely that at least some of the secondary quartz is unrelated to the period of metasomatism but was introduced by solutions passing through later fractures.

Perhaps the most striking example of secondary quartz is met with in a metasomatic body a short distance from the quartz pipe west of the Blue Stack. Here the cleavage surfaces of poikilitic quartz crystals an inch in diameter may be seen on rock surfaces, particularly in bright sunshine. The secondary quartz is associated with minute crystals of chlorite and ilmenite.

(iii). *Muscovite-rich rocks.*—A special type of alteration is found in a body close to the Lough Belshade fault a few yards north of Lough Nacollum. In the hand specimen the rock is seen to be composed of pink feldspar and a pale green mineral which, under the microscope, is seen to be a colourless mica which constitutes some 30% of the rock as clusters of crystals and as flakes scattered through and replacing plagioclase. The feldspar is mainly albite, always perfectly fresh, with very subordinate microcline, and there is a little secondary quartz, little groups and nets of rutile needles, ilmenite, and broad crystals of apatite.

The mica has a small optic axial angle similar to that in Caledonian dykes in the Cronamuck River, described in the sequel, and as will be seen the metasomatized rock has other features in common with the Cronamuck dykes. The alteration probably involved the replacement of both the potash feldspar and the quartz by albite, the liberated potash being concentrated in the residual solutions, later to react with the rock to give muscovite.

VI. Minor Intrusions.

The granites of the Barnesmore Complex are cut by two distinct dyke swarms, and over 100 members of each have been found. The dykes of the two swarms are readily distinguished in the field by differences in the nature of the jointing and resistance to weathering, by the form of the intrusions, and by the presence or absence of marginal chilling and amygdales. The rocks of the two swarms are equally readily distinguished petrographically, the newer dykes being mainly olivine-dolerites and crinanites, with glassy rocks at the acid extreme, whereas the older dykes are lamprophyres, microdiorites and porphyrites, with granodiorite-porphyries and quartz-albitites at the acid extreme.

The officers of the Geological Survey of Ireland apparently did not fully appreciate the above age relationships. They recognized two groups of dykes, namely the basalts and dolerites, which they regarded as Tertiary, and the pitch-

stones, felstones and felstone-porphyries. They found evidence that some of the latter cutting the schists near the granite were pre-Carboniferous in age, and it seems that the pitchstones and felsites of the newer swarm were regarded as of the same age. Certainly the more basic dykes cutting the Complex were not separated into two swarms.

(*a*) *Age relations.*

There can be barely any doubt that the rocks of the newer swarm are Tertiary. Although direct evidence in the Barnesmore area indicates only their post-Lower Carboniferous age, the Barnesmore dykes are clearly continuous with the swarm radiating from the Tertiary volcano of Slieve Gullion, and dykes of similar field character and trend and identical composition cut the Chalk of County Antrim and are associated with the overlying Tertiary lavas.

It is equally certain that the dykes of the older swarm are closely related in age to the granites of the Barnesmore Complex and followed the emplacement of the granites after a very short time interval. The absence of well-marked chilled margins would appear to indicate that the granites, though solid, were not cold when the dykes were intruded ; the Tertiary dykes on the other hand are invariably chilled. Unlike the Tertiary dykes, which have their own contraction joints, the older dykes share in the jointing of the granites. Although in some cases clearly injected along lines of fracture, the dykes themselves are crushed by later movements along the same fractures, and the older dyke swarm was thus probably intruded at about the same time as the initiation of the faults. That the Tertiary dykes post-dated the faulting is abundantly clear in the general absence of crushing, even in the several dykes cutting the broad belts of crushed granite accompanying the larger faults. Near the top of the col north-east of Lough Belshade, in fact, one three-foot dyke of olivine-basalt which has suffered no deflection or crushing crosses the Lough Belshade fault, a fault along which the granites have been shifted laterally a distance of more than two miles.

The presence of pebbles of types similar to the microdiorites of the older swarm in the Lower Carboniferous conglomerates near Lough Nacollum indicates a pre-Carboniferous age for the swarm, and their Caledonian age is supported by the petrographical character of the rocks.

(*b*) *Caledonian minor intrusions and vents.*

The dykes of the older swarm, fig. 6, occur throughout the Complex, but are most abundant in the area of the Cronamuck River, where they constitute a distinct swarm associated with breccia vents. The larger number of the dykes trend between N. and N.E., but there is a second group, less well developed, trending about S. 35°E. The presumed Caledonian dykes mapped by the Geological Survey to the south of the Complex show a general N. to N.E. trend, but how far this is typical of Donegal as a whole is not known. The average width of sixty measured dykes is three feet ; the greatest, fifty feet. The larger dykes are always of the

more acid types, the more basic lamprophyres and microdiorites rarely exceeding six feet in width.

A distinctive feature of the minor intrusions in general is their tendency to form networks of ramifying veins and squirts, fig. 7, and even normal dykes commonly send off small veins along their margins. Three good examples of these vein-networks may be especially noted, namely around the quartz pipe west of the Blue Stack, on the ridge north of Croaghanirwore west of the Cronamuck River, and at the Pollakeeran vents (fig. 8). The closeness of a vein network to the quartz pipe seems to indicate a close genetic relationship between the two, and elsewhere

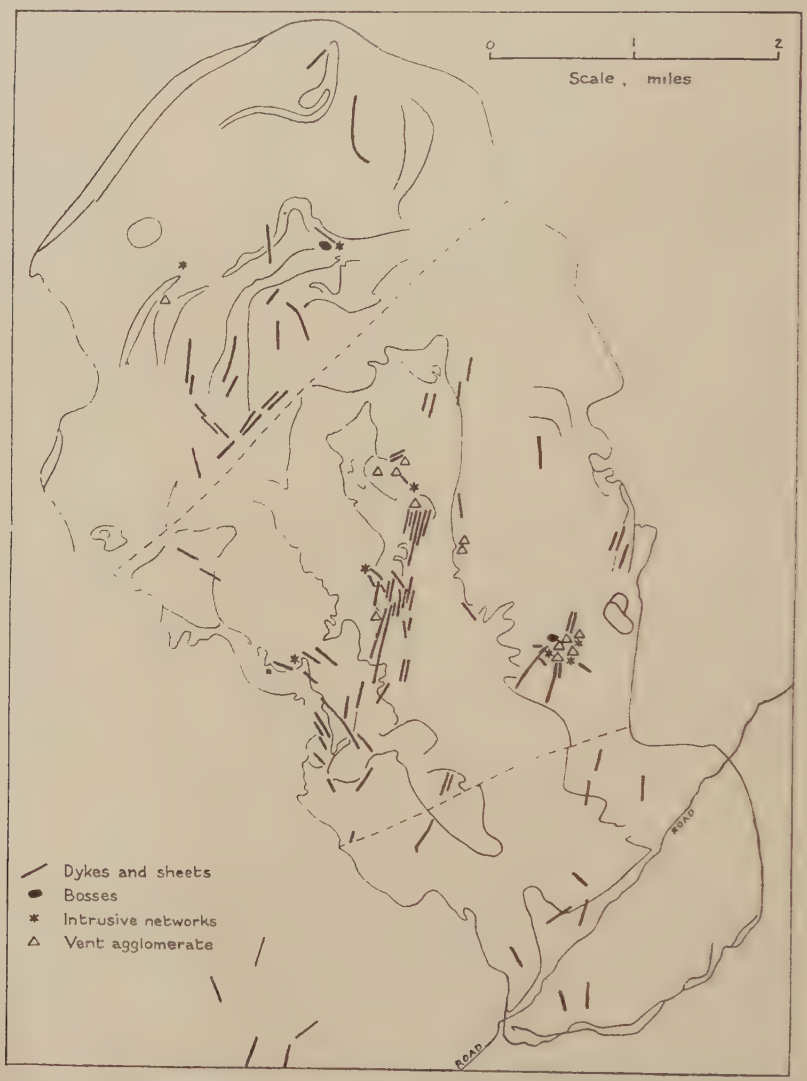

FIG. 6.—The distribution of Caledonian minor intrusions in the Barnesmore Complex. On this map compensation has been made for the lateral movement along the Lough Belshade and Barnes Lough faults.

in the Barnesmore Complex a similar relationship between networks of intrusive veins and large masses of quartz or networks of quartz veins has been noted. As far as we are aware, similar ramifying networks of veins of intrusive dyke-rock have not been described from other British Caledonian plutonic complexes.

In addition to the dykes a few sheets have been found, intruded along inclined faults or flat-lying joint planes, and three small bosses are known to occur within

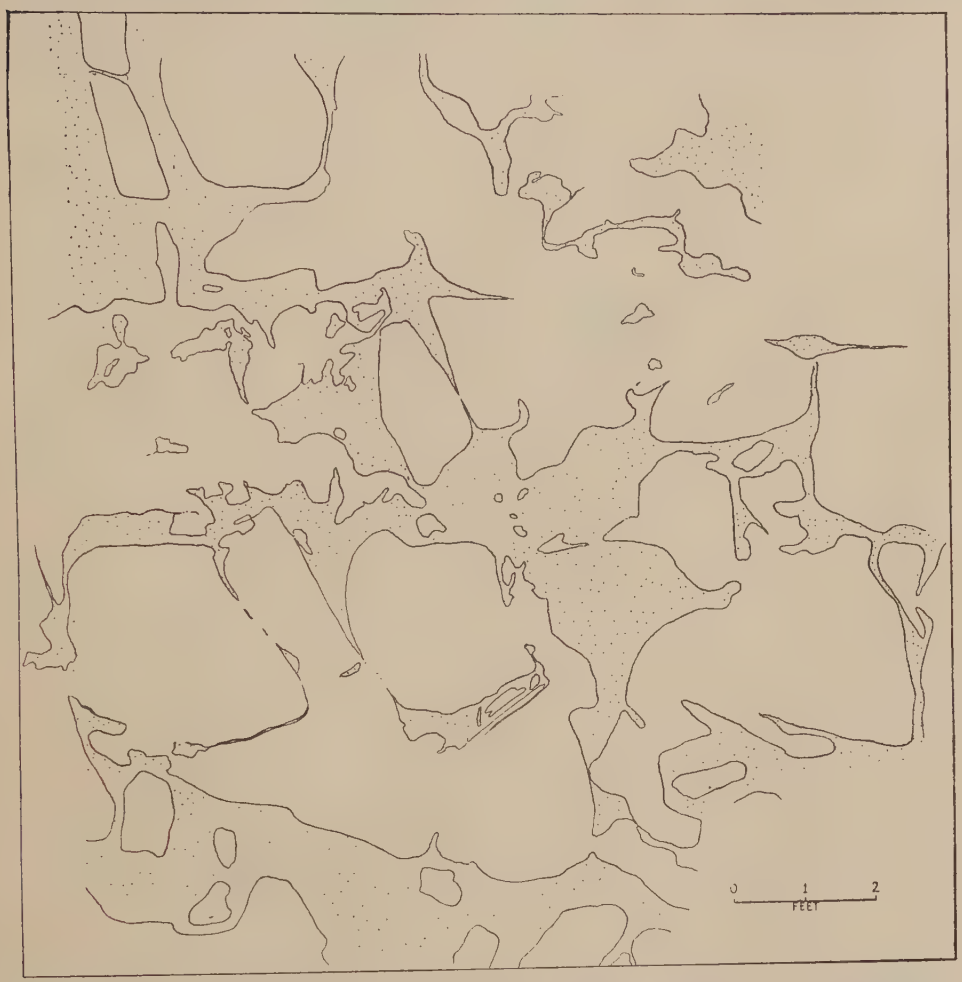

FIG. 7.—Vein network of quartz-microdiorite cutting the granite near the Croaghgorm quartz pipe.

the Complex. Of these the largest are the Lough Aduff boss, measuring 50 by 35 yards, the boss of quartz-microdiorite on the ridge north of Croaghanirwore, associated with a network of veins and dykes of intrusive rock, and the boss of acid rock associated with the Pollakeeran vent (see fig. 6). What may possibly be an elongated intrusion occurs on the hill three-quarters of a mile north of Lough Nacollum in the west of the Complex. The relations of this body have not been

satisfactorily solved, but it is perhaps more likely that it is an inclusion of G1 in the main granite.

Two large bosses of granodiorite-porphyry cut the Dalradian schists to the south-west of the Barnesmore Complex. The more southerly is composed of a rather heterogeneous assemblage of acid rocks, but the other is more constant in texture and composition; it contains inclusions up to 1 foot in diameter of Dalradian schists. Rock types similar to those composing the bosses are found as dykes within the Barnesmore Complex, and although more direct evidence is lacking we regard the two bosses as part of the Caledonian dyke swarm.

FIG. 8.—Map of the Pollakeeran vent and associated Caledonian minor intrusions.

In certain parts of the Barnesmore Complex the granites are cut by vents containing agglomerate or breccia. Six of these vents have been located (fig. 6; also Plate 14). It is significant that they lie approximately on a straight line passing through the centre of the Complex though not quite coincident with its major axis. When allowance is made for faulting the vent on the Blue Stack ridge lies on the prolongation of the line across the Lough Belshade fault. The largest of these vents occurs in the upper part of the valley of the Pollakeeran River (fig. 8). Within an area of 250 by 200 yards there are ten areas of breccia containing Dalradian fragments, the intervening granite being much fractured but free from schist

fragments. The breccia consists of angular fragments of Dalradian schists and amphibolite ranging in size to four feet in length, the average length being about six inches (fig. 9), embedded in a matrix of comminuted granite and schist. Although the vents are clearly related to the Caledonian dyke swarm there are no fragments of the dyke-rocks within the breccia. Numerous intrusions occur in the vent area, and often cut through the agglomerate in the form of dykes, bosses, and vein networks, ranging in composition from basic to acid. The dykes show a rough radial arrangement about the centre of the vent.

FIG. 9.—Drawing of one square yard of rock surface of breccia or agglomerate in the Pollakeeran vent. The blocks are of schist and amphibolite.

There is no need to describe the other vents in detail; they are essentially similar to the Pollakeeran vent, though smaller. All are closely associated with dykes and squirts of igneous rocks of the Caledonian dyke swarm. The vent N.W. of Brown's Hill contains fragments of Dalradian schist, aplogranite, and small pebbles of quartz, embedded in a finely comminuted matrix of aplogranite. The vent N.E. of Croghgorm is very small and consists of a few fragments of schist embedded in finely comminuted aplogranite and intimately associated with veins of quartz-microdiorite.

Several pipes of quartz and networks of quartz veins that bear no obvious relationship to faulting are scattered through the Complex. The most prominent is the Croaghgorm pipe near the western margin of the Complex. It is composed entirely of milky quartz with an average grain-size of several inches. The pipe is nearly circular in plan, measuring 85 by 75 feet. The quartz has resisted weathering better than the adjacent granite, and forms a conspicuous knoll about fifteen feet high. The contact with the granite is not exposed. About one-third of a mile south of this pipe is a second, measuring forty by twenty feet, and associated with a network of quartz veins. Nearby is a small breccia-vent and squirts of dyke-rock. A few hundred yards further to the south is a rectangular area of granite and aplogranite measuring 150 by 50 yards which is riddled with veins of milky quartz.

In one respect the Caledonian dykes of the Barnesmore Complex may differ from corresponding dykes elsewhere in the British Isles, in having been injected with considerable violence. The highly irregular form of many of the intrusions has already been mentioned, and ramifying networks of veins and stringers can be regarded as highly characteristic of the swarm as a whole. Again, in several places, dykes are associated with a highly irregular plexus of veins of quartz and the close field association suggests a genetic relationship. However it is in the vents that the most striking effects are seen. The vents, it will be recalled, are small and irregular in form, and enclosed by badly fractured granite. They consist of angular blocks of schist of all sizes embedded in a matrix of comminuted granite. That the vents are true eruptive vents reaching to the surface is doubtful, and the impression given in the field is that they are due to the driving upwards with great violence of wedges of Dalradian schist into the granite, the wedges being smashed up in the process. This Dalradian, identical with that found in the vicinity of the Complex, must have been derived from at least one thousand feet below the present level of the vents. In passing it should be pointed out that the vents provide indirect evidence of the existence of a floor to the Complex.

It has already been noted that the older dykes show two main trends, roughly N.N.E. and S.S.E. differing from the normal N.E. trend of the Caledonian dykes of Scotland and eastern Ireland. However several of the Caledonian igneous complexes of Britain have dyke swarms trending in two main directions. Nockolds' (1940) map of the Garabal Hill–Glen Fyne igneous complex shows two sets of dykes and sheets trending approximately north-south and east-west respectively, and the dykes in the vicinity of the Criffel-Dalbeattie complex also show two distinct trends, approximately N.E. and N.W. The closest parallel with the conditions which obtain in the Barnesmore Complex is, however, provided by the Cheviot granite. The granite is surrounded by Lower Old Red Sandstone lavas cut by numerous dykes, which fall into two distinct sets trending N.N.W. and N.N.E., and intersecting at about 60°. Anderson (1932, p. 98) writes : " Within the igneous area the silica veins, fault breccias, and crushes have the same direction as the dykes . . . . it seems probable that . . . . the crushes came first, and afterwards many of the dykes utilized these planes of weakness."

Where the dykes form a single well-marked swarm, for example those associated with the Etive, Ben Nevis, Glencoe, Cruachan, and Newry granites, regional tension has been responsible for the localization of the dykes; where the dykes of the swarm fall into two distinct sets it is probable that tension was less pronounced, and the dykes were forcibly intruded mainly along pre-existing fractures and joints.

TABLE 2.

Modal analyses of Caledonian dyke rocks from the Barnesmore Igneous Complex.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Plagioclase												
phenocrysts	3·6	16·6	17·1	12·2		4·8	4·7		3·0	4·0		
groundmass	23·0			44·1	30·4	34·3	57·1	43·0	50·3	58·0	65·5	73·2
Quartz												
Phenocrysts	1·3	8·0	6·0									
groundmass	32·0			21·0	33·4	26·7	16·3	34·7	21·6	17·0	12·1	0·9
Potash feldspar												
phenocrysts		4·8	6·4									
groundmass						*	*					
Biotite												
phenocrysts		2·8										
groundmass			8·4	10·5		5·0	9·5	4·0	21·5	20·0	10·1	*
Hornblende												
phenocrysts									2·0			8·4
groundmass								5·1			11·4	
White mica	38·0			11·4	30·0	18·0	11·9	12·6	*	*	*	*
Chlorite	*	*	*	*	1·8	*	*	*	*	*	*	*
Magnetite		*	*	*		0·1	*	*	*	*	*	*
Rutile				}	0·3			*				
Sphene			*	*					*	*	*	
Zircon					*							
Pyrite	1·8				4·1							
Apatite	*	*	*	*	*	*	*	*	*	*	*	*
Quartz/plagioclase intergrowth		*				11·1						
Combined accessories ...	0·3			0·8		0·5	0·6	1·6	1·0	0·9		
Groundmass		68·0	62·1									

TABLE 3.

1. Analysis of quartz-albitite rock from the Cronamuck River. Analyst, W. H. Herdsman.
2. Calculated analysis of white mica in the quartz-albitite.

	1.	2.
SiO_2	70·48	52·4
Al_2O_3	15·57	26·8
Fe_2O_3	0·50	1·3
FeO	0·76	1·8
MnO	Tr.	
MgO	0·82	2·1
CaO	0·44	0·3
K_2O	2·92	7·4
Na_2O	2·27	
H_2O^+	0·62	1·6
H_2O^-	2·58	6·3
CO_2	nil.	
P_2O_5	0·08	
TiO_2	0·37	
FeS_2	2·70	

Petrography.

The Caledonian dyke-rocks range from basic lamprophyric to acid granodioritic and adamellitic types. Six main types have been distinguished, but there are continuous gradations from one to the other. The most acid types are granodiorite-porphyries and quartz-albitites. The latter is an unusual group of rocks consisting of quartz, albite and muscovite. They grade into quartz-diorite-porphyrites, quartz-microdiorites, and microdiorites. The characteristic feature of the porphyrites and quartz-microdiorites is the association of a high content of ferromagnesian minerals with a fairly high content of quartz. Texture apart, they are quartz-lamprophyres, that is microdiorites containing conspicuous phenocrysts of either hornblende or biotite or both. The most abundant types are the quartz-microdiorites, quartz-diorite-porphyrites, and microdiorites, which together constitute perhaps 90% of the dykes.

The granodiorite-porphyries, quartz-microdiorite-porphyrites, and lamprophyres, are always conspicuously porphyritic, containing phenocrysts of feldspar and or the ferromagnesian minerals. The groundmass ranges from fine-grained to very fine-grained, as in some of the granodiorite-porphyries and lamprophyres. The quartz-microdiorites and microdiorites are usually equigranular and rarely porphyritic. A characteristic feature of many of the acid dykes, particularly the quartz-albitites, is irregular, granophyric quartz-plagioclase intergrowths. Spherulitic texture is seen in a few of the more acid rocks. The individual spheruliths may be composed entirely of plagioclase or of an intergrowth of quartz and plagioclase.

Flow structure is very marked in a few of the Caledonian dykes, and is readily seen in the field. Flow-banding parallel to the margin is conspicuous in a dyke near the quartz vein-network north of Mullaghnadreesruhan. A large number of dykes also exhibit a more or less well-defined parallelism of biotite flakes when seen in thin section.

Xenoliths occur within a few of the Caledonian dykes and bosses. They are rarely more than an inch long, but in the northern of the two Nameeltoge bosses west of the Complex are schist xenoliths a foot long.

All the Caledonian dyke-rocks show some degree of alteration. This has resulted in the partial or complete replacement of hornblende by biotite, or by chlorite or other minerals, the replacement of biotite by chlorite and iron ores, and of plagioclase by white mica and calcite.

Although some of this alteration is due to weathering, most of it is the result of hydrothermal alteration shortly after the dykes were intruded and whilst they were cooling. In the acid rocks, particularly in the quartz-albitites, the main effects are seen in the development of sericitic mica which, in a few cases, becomes the main constituent of the rock. Biotite in these rocks is represented by chlorite, iron ore and rutile. In the basic rocks hydrothermal alteration is most clearly seen in the breakdown of the ferromagnesian minerals, but partial sericitization of plagioclase and development of calcite has also occurred to a greater or lesser extent in all these basic rocks.

Granodiorite-porphyry.—Two large bosses of granodiorite-porphyry occur a short distance west of the Barnesmore Complex near Lough Nameeltoge. The rocks are rather variable but are always acid and markedly porphyritic with phenocrysts of andesine-oligoclase, quartz, microcline-perthite, and biotite, in a fine- or very fine-grained groundmass of plagioclase and quartz, along with smaller amounts of potash feldspar and biotite. An interesting and not uncommon feature of the microcline phenocrysts is its habit of forming granophyric intergrowths with quartz. A mode of typical rock is given in Table 2, 2.

A few rocks which can be classified as granodiorite-porphyry cut the granites of the Barnesmore Complex. A typical example occurs as a sheet one foot thick west of Lough Belshade. Phenocrysts of plagioclase, quartz, microcline-microperthite and biotite lie in a fine-grained groundmass, and in composition and texture the rock is similar to that of the Nameeltoge bosses.

Quartz-albitites.—The quartz-albitites are characterized by the association of quartz and albite, with white mica. The Cronamuck dyke is the most leucocratic ; it is about six feet wide, and cuts the granite at about 800 feet in the Cronamuck River. The rock is light grey in colour, and there is abundant pyrite in small crystals scattered through the rock. It is sparsely porphyritic, with small phenocrysts of plagioclase and quartz. The feldspar is albite ($\beta = 1 \cdot 532$, indicating about An 5) and is usually mottled by flakes of white mica. Muscovite is the most abundant constituent of the rock. It has a very small optic axial angle. Chlorite, sphene and rutile are common accessory minerals, in part secondary after biotite. A mode and analysis of this rock are given in Table 3. The only other dyke of closely similar composition is probably related to the Cronamuck dyke, occurring about 100 yards further upstream in the Cronamuck River. It contains rather more pyrite and chlorite, and less muscovite.

The abundance of white mica in these rocks calls for some discussion. It is found in practically all the Caledonian dyke rocks of the Complex, but is abundant only in the quartz-albitites. It occurs not only in the Cronamuck dyke but also in the granite immediately adjacent to it, and is clearly, therefore, not primary. It is likely that the solutions responsible for the formation of the mica were given off by the dyke itself rather than that they were later than, and unrelated to the dyke. Potash was probably concentrated in the hydrous residuum formed during the cooling of the dyke ; this potassic residuum then attacked the feldspar to form muscovite. Analysis of the mica, calculated from the mode and chemical analysis of the rock (Table 3, 2) shows it to be a normal potassic mica.

Quartz-albitite dyke-rocks have been described from only a few localities, from Cape Willoughby, Australia (Tilley, 1919), Encounter Bay, South Australia (Browne, 1920), and Gubben, Sweden (Holmquist, 1906). A large dyke of " soda-syenite-granophyre " from the Mother Lode district of California is described by Ransome (1900, p. 5) as being composed mainly of albite, quartz, and muscovite.

Most of the related dykes within the Barnesmore Complex are more basic than the Cronamuck dykes, being richer in ferromagnesian minerals, and with a more basic plagioclase. The Lough Aduff boss provides a typical example. In this rock the phenocrysts of plagioclase (about An 12) range up to 1 cm. in length, and are embedded in a groundmass of quartz, albite, and biotite. White mica is abundant as small flakes. Another type, found as a small dyke in the Cronamuck River area, is markedly porphyritic, with plagioclase phenocrysts up to 4 mm. in a groundmass which is very rich in quartz, with a considerable amount of biotite, largely chloritized, and small amounts of plagioclase. Apatite is an abundant accessory.

Quartz-diorite-porphyrite.—Rocks of this type contain phenocrysts of plagioclase and occasionally of ferromagnesian minerals in a groundmass of plagioclase, biotite and/or hornblende, and quartz. The quartz content ranges up to 20%, and the ferromagnesian minerals form more than 10% of the rock. There are transitional types between these rocks and the

quartz-albitites. A typical quartz-diorite-porphyrite composes the large boss and vein-network on the north-east side of Croaghanirwore ridge. The phenocrysts, of andesine-oligoclase and a little biotite, are exceptionally up to 2 sm. in length. Quartz forms 25% of the groundmass.

Quartz-microdiorite and microdiorite.—These are by far the most abundant types within the Complex. They are dark and fine-grained, and either non-, or poorly porphyritic. The phenocrysts are generally of plagioclase, and very rarely of ferromagnesian minerals. These rocks frequently show fluxional foliation due to parallelism of the ferromagnesian minerals and the plagioclase laths. Mineralogically the quartz-microdiorites are characterized by the combination of a fairly high quartz content (5–20%) with a high content of ferromagnesian minerals, chiefly biotite. In the microdiorites the quartz content falls to below 5%.

A typical quartz-microdiorite occurs as an irregular vein-network in the granite of the Cronamuck River area near one of the vents. The sparse microphenocrysts of plagioclase do not exceed 1 mm. in length and show well-defined normal-oscillatory zoning, the zones ranging from An 40 to An 25. A few phenocrysts of hornblende up to 1.5 mm. in length also occur; they have been partially or entirely replaced by biotite, epidote, and iron ore. Such replacement of hornblende is quite characteristic of the quartz-microdiorites and microdiorites as a whole. The groundmass of the rock consists of an equigranular aggregate of plagioclase, quartz, and biotite. A mode of this rock is given in Table II, 9, and 10 and 11 represent further types. In some of the quartz-microdiorites the groundmass quartz and plagioclase form a granophyric intergrowth similar to that in the quartz-albitites. In quartz-microdiorites near the Croaghgorm quartz pipe plagioclase occurs in radiating aggregates, sometimes intergrown with quartz.

A typical microdiorite occurs as a vein cutting granite near the Croaghgorm quartz pipe. The rock is very slightly porphyritic, with plagioclase phenocrysts not exceeding 1 mm. in length, and exhibiting oscillatory zoning with a range in composition of An 45 to 25. The more calcic zones are altered to calcite and sericite. Small phenocrysts of hornblende have been entirely pseudomorphed by biotite, chlorite, carbonate and iron ore. The groundmass of the rock is composed largely of plagioclase and biotite in crystals averaging 0.1 mm. long.

A distinctive type of microdiorite occurring as a small dyke on Binmore at the western end of the Complex contains abundant acicular crystals of hornblende aligned to give the rock a distinct lineation. The crystals, which are up to 2.5 mm. long, are zoned, the core having $Z : c = 16°$ and pleochroism X colourless, Y pale brown, Z brown, and the mantle $Z : c = 23°$, pleochroism X colourless, Y pale green, Z green. The zones grade into one another. Plagioclase (about An 30) is the main constituent of the rock.

Lamprophyres.—True lamprophyres are decidedly rare: only three examples were found in the seventy or so dykes examined in thin section. In all these rocks hornblende or biotite forms conspicuous phenocrysts, and phenocrysts of plagioclase are either rare or absent. The rocks may therefore be described as camptonites. A typical camptonite dyke two feet wide from the extreme north-western part of the Complex near Clogher Hill is composed of phenocrysts of hornblende and a few of plagioclase in a groundmass of idiomorphic plagioclase and biotite. The plagioclase phenocrysts are very small, never exceeding 1 mm. in length. They are strongly zoned from cores of labradorite-andesine to mantles of medium oligoclase. The hornblende phenocrysts are up to 2 mm. long, and are well-formed. Groundmass plagioclase crystals average 0.02–0.1 mm. and approximate in composition to An 20. Magnetite and apatite are abundant accessory minerals. A mode of this rock is given in Table II, 12. The other lamprophyres sectioned contain phenocrysts of hornblende and biotite only.

(*c*) *Tertiary dykes.*

A well-marked swarm of Tertiary dykes with predominant N.W.–S.E. trend cuts the Barnesmore Complex, and the known dykes are plotted on the map, fig. 10. In view of the readiness with which the dykes are eroded it is certain that many have been missed during the course of the field work, and the apparent scarcity of dykes in the adjacent Dalradian is no doubt due to the poor nature of the exposures. The dykes range in thickness up to more than 30 feet, the average from measurement of 80 dykes being 8 feet.

Practically all the dykes show a well-developed prismatic jointing normal to, or a closely-spaced platy jointing parallel to the margins, neither bearing any relation to the jointing in the adjacent granite. Mainly on account of the jointing the Tertiary dykes as a group are much less resistant to weathering than the granites or the dykes of the older swarm, and they are often followed by streams. Small gorges have been eroded along the course of several of the dykes ; one of the most striking is the trench up to 40 feet deep excavated along the large multiple dyke near the north-eastern end of Lough Belshade, with vertical walls to which small portions of the chilled margin of the dolerite adhere in places.

True composite dykes have not been observed, but several examples of multiple dykes are known, in which the inner component presents a chilled contact against the outer. The best example is the quartz-dolerite dyke with a quartz-felsite inner part near the north-eastern end of Lough Belshade. The Croaghnageer dyke represents a special case in which an outer part of dolerite grades into an inner dolerite packed with xenoliths and xenocrysts derived from the granite. An unusual type of heterogeneity is found in a very large dyke of olivine-dolerite exposed in the upper reaches of the Owengarve River due north of Glascarns Hill. The contacts of the dyke with the country rock are not seen, but the dyke, which outcrops in the stream for a distance of nearly half a mile, is at least thirty feet wide. It shows a marked vertical banding parallel to the length of the intrusion, the bands, which are of contrasted mineral composition, being an inch or so wide.

Some of the Tertiary dykes contain layers of amygdales parallel to the margins. These amygdales which, except in the pitchstones and felsites, rarely exceed a few mm. in diameter, contain zeolites and calcite or, in the more acid types, quartz, calcite, and chlorophaeite. There is evidence that in some cases the quartz paramorphs cristobalite, but no undoubted cristobalite has been found. Cognate xenoliths have not been observed in any of the dykes, but xenoliths and xenocrysts derived from the granite have been observed in a number of cases, notably in the Croaghnageer dyke. Auto-intrusions, in the form of coarse-grained segregation-veins have been found in several dolerite dykes, and veins of quartz-felsite up to two inches wide cut the leidleite dyke half a mile due east of the summit of Croaghconnellagh. Metamorphism of the granite by basic dykes is often visible in the field, though the effects are usually slight. In the case of the Croaghnageer and Pollakeeran dykes, however, there has been local partial or complete fusion of the granite. The fusion of granitic rocks to glass has seldom been described, and in 1939 Larsen and Switzer were able to refer to only six examples in the literature.

Most of the Tertiary dykes are more or less vertical and probably unrelated to pre-existing fractures, but in several instances intrusion along faults has been found ; thus an olivine-dolerite dyke has been intruded into the inclined fault west of Cronloughan, In the stream running due north into Croaghanard Lough, several thin dykes have been injected along joints, and similar examples could be cited from other parts of the Complex. No serious attempt has been made to determine the length of individual dykes, but several have been traced for distances of one to two miles. Excellent examples of deflection of dykes approaching major

faults are to be found at the western end of Barnes River valley. This deflection is unaccompanied by any fracturing of the dykes, which are obviously later than the faulting. Further evidence of this is provided by a three-foot dyke, exposed in the col N.E. of Lough Belshade, which crosses the fracture-zone of the Lough Belshade fault without itself being crushed or broken. Several other dykes are known which enter the crushed granite of this fault without having suffered any crushing. Exceptional are two dykes of Tertiary type which have themselves been intensely crushed; they lie almost on the fault separating the Dalradian and Carboniferous in the southern of the two bosses of granodiorite-porphyry west of the Complex.

Three out of every four Tertiary dykes cutting the Barnesmore Complex are olivine-dolerites and crinanites, and the former are remarkably uniform in composition. The only known dyke of quartz-dolerite known definitely to belong to the Tertiary swarm forms the outer component of the large multiple dyke at the north-eastern end of Lough Belshade; two crushed and much-altered dykes of dolerite containing a good deal of interstitial quartz cut the southern of the two bosses of granodiorite-porphyry west of the Complex. Although crushed, there is little doubt they belong to the Tertiary swarm. It is not certain whether or not the interstitial quartz is secondary.

Several dykes of leidleite are known, and they pass into the pitchstones and felsites, which constitute about 15% of the dykes. True pitchstones may occur both as individual dykes and as marginal selvages to the felsite dykes. The rocks are usually porphyritic.

Distribution of Acid Dykes.—The distribution of the pitchstones and felsites shows some features of considerable interest, for, as may be seen from the map, fig. 10, these dykes are confined to an elongated area crossing the Lough Belshade fault and trending N.W.–S.E. This distribution reminds one of the map by Harker (1904, p. 387) showing the distribution of the Tertiary pitchstones of Skye, which occur along a line trending N.W.–S.E. and coincident with the axis of the Tertiary granites. It is possible that the acid dykes of the Barnesmore area overlie a Tertiary granite which has not yet been revealed by erosion, and that the apparent concentration of the Tertiary dyke swarm in this area is related to this Tertiary granite.

The dykes of pitchstone and felsite in the Barnesmore Complex are nearly always amygdaloidal, and often the amygdales are elongated in the direction of flow of the magma. The direction of flow at a particular point is the resultant of the effect due to two factors: a local factor, due to irregularities in the dyke, and a regional factor due to the source and general direction of injection of the magma. If sufficient observations are made of the orientation of the amygdales in a dyke it is possible to eliminate the local factor and thereby determine the direction of injection of the magma from its source. This has been attempted for four of the Barnesmore dykes, and the results included on the map, fig. 10. Although only limited conclusions can be drawn from such restricted data, there is an indication that the acid magma was intruded from a source in the vicinity of Lough Illanmore and at a depth of two or three miles below the present surface. Harker (1904,

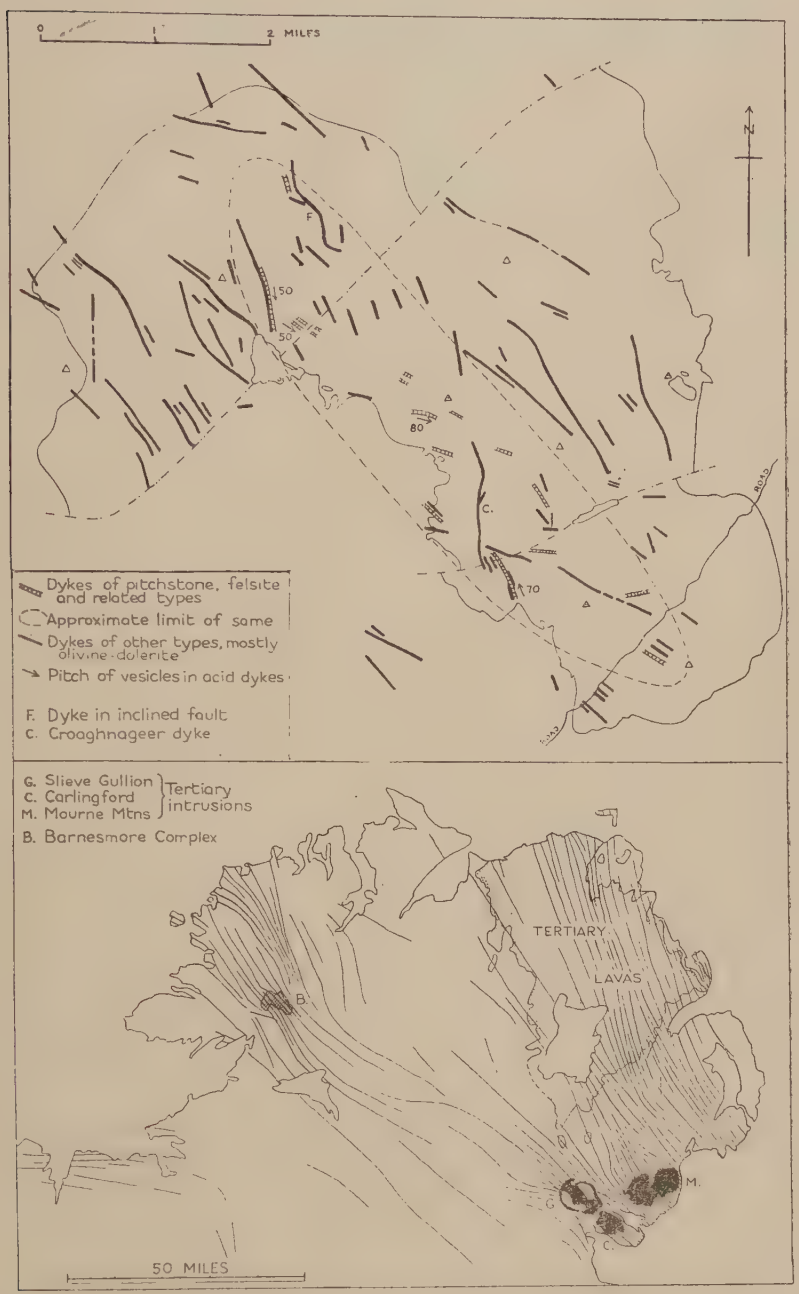

FIG. 10.—The Tertiary dyke swarm. The upper map shows the known dykes cutting the Barnesmore Complex. The lower shows the distribution of the Irish Tertiary dyke swarms, compiled, with modifications, from the maps of the Geological Survey of Ireland. Only a small proportion of the dykes are shown.

p. 391) studied the orientation of the amygdales in the Skye dykes, but did not reach any conclusions regarding their source. In an area where dykes bearing elongated amygdales or, indeed, linear structures of any kind, are abundant, a study of the orientation may give results of considerable interest and value.

VII. Faulting.

The largest fault in the area is the Lough Belshade fault, a tear fault with demonstrable lateral displacement of about 2.2 miles. Evidence has already been presented to show that the fault may also have a vertical displacement with a downthrow to the S.E. of the order of 2,000 feet. In a few places more or less horizontal slickensiding has been observed, and the fault-plane is vertical. The fault is accompanied by a belt of intense crushing up to 100 yards wide, and there has been a limited amount of mineralization with calcite, quartz, hematite, and pyrite. The granite is much fractured and traversed by quartz veins to a considerable distance from the fault.

The Barnes Lough fault appears to represent a second tear fault, later than the Lough Belshade fracture, which is bent and offset by it, and differs in having a dextral rather than a sinistral displacement. A fault of a different kind is exposed in the vicinity of Cronloughan. It is not vertical, but dips about 50° N.E.; this is beautifully illustrated by the manner in which its outcrop crosses the two ridges walling the Cronloughan corrie. The fault is very well exposed in gullies descending from both sides of the northern ridge, and also to the south of the Lough, and it is in part followed by dykes of the Caledonian and Tertiary swarms. In places vertical offshoots from the main shear belt cut the granite above, and one of these is followed by a Tertiary dyke.

This fracture is probably a reverse or high-angle thrust fault. It is possible that the aplogranite sheets found at the base of the western wall of the Cronloughan corrie west of the fault represent a continuation of the uppermost Lough Aduff sheet which, between here and Lough Aduff, is concealed below G2, and that the aplogranite sheet of Cronloughan itself, east of the fault, is this same sheet which has been thrust upwards through a distance of several hundred feet.

A fracture similar to the Cronloughan fault, but not indicated on the map, Plate 14, in view of the lack of evidence of displacement of the granite, is found on the platform above and to the north-west of the Lough Belshade corrie. This fracture is inclined north-west at a small angle, and along part of its course is followed by an acid dyke belonging to the Caledonian swarm, now intensely crushed. This fracture may be traced from Mullaghnadreesruhan through Binmore, where it gives rise to a bog-filled depression, and thence to the col between the Blue Stack and Lough Aduff Hill.

VIII. Summary and Conclusions.

Hitherto uncertain, the age of the Barnesmore Complex has now been established. The granites were intruded into Dalradian schists after the folding and regional metamorphism of these rocks. Lower Carboniferous conglomerates occur in the Barnesmore area but do not come into contact with the intrusive rocks

of the Complex. Although not containing pebbles of granite they do contain igneous rocks of types which may readily be identified amongst the dykes of the older swarm which cut the Complex, dykes which are closely matched by typical Caledonian dykes associated with the Newer Granites of Scotland and totally unlike those associated with the Tertiary granites. We conclude, therefore, that the Barnesmore granites were intruded at some time after the close of the Caledonian orogeny and before the deposition of the Lower Carboniferous sediments. The age may perhaps be further limited by correlation of the Lough Belshade tear fault with similar fractures in the Scottish Highlands which, according to Anderson (1942) and Kennedy (1946) were initiated and suffered most of their movement prior to the deposition of the Upper Old Red Sandstone.

Incidental evidence supports the same conclusion. Thus it is becoming evident that deuteric alteration of the same general type as is met with at Barnesmore is characteristic of several of the British Caledonian granites, while alteration of the Tertiary granites results rather in the formation of greisen and kaolin. Granodiorite, found at Barnesmore, is a common member of British Caledonian granite masses but is absent from the Tertiary. The Barnesmore granites can readily be matched by Caledonian granites from the Scottish Highlands, particularly the north-east Grampians. The absence of drusy cavities from both stands in marked contrast to their abundance in some of the Tertiary granites. However, although a Caledonian age is established, the presence of acid dykes in the Tertiary swarm, and their distribution, combined with the convergence and density of the swarm as a whole would appear to point to the existence of a Tertiary granite not yet exposed by erosion below the Complex.

The Cronamuck granodiorite, G1, was emplaced first, followed closely by the main granite, G2. After G2 had consolidated but before it had cooled appreciably the members of the sheet complex were injected into it, accompanied and followed by the intrusion of a network of aplite veins and dykes, and the older hydrothermal quartz veins were formed soon afterwards. Later, the localized uprise of alkaline solutions was responsible for the deuteric alteration of the granites. This was succeeded by the intrusion of the members of the Caledonian dyke swarm, often in fractures which were initiated at this time, but the development of the numerous faults which cut the Complex took place mainly after the period of injection of dykes and drilling of vents. The widespread joints and fractures filled with comby quartz were probably formed at the same time as the faults. The region suffered erosion during early Carboniferous times, but apparently the roof of the granite mass was not breached until later. The final episodes of which we have records were the intrusion of the Tertiary dyke swarm and the erosion of the mountains to their present condition.

The present work has shown that there are several constituent granites in the Barnesmore Complex, and that into a coarse-grained granite (G2) there have been intruded sheet-like masses of aplogranite of various types, designated collectively as the " sheet complex". The shape of the sheet complex is particularly interesting, and the emplacement of it and the main granite is explained in terms of subsidence of large blocks of country rock. A new descriptive term " igneous arch " is in-

troduced for an arch-like sheet of intrusive rock intruded into massive, unlayered igneous rock. The two igneous arches which have been recognized in the Barnesmore Complex are attributed to subsidence of blocks of the main granite.

In the British Isles the closest parallel to the structures of the sheet complex is probably to be found in the Etive Complex of Scotland (Anderson, 1937). Here the fine-grained acid granite of Meall Odhar is intruded into the Cruachan granite. Anderson's account suggests that the Meall Odhar granite forms numerous sheets, rather like those at Barnesmore, and he states (1937, p. 498), " On the S. and W. sides of the range . . . . in the Allt Cruiniche and in the various head streams of the Allt Criche, there are numerous bands of Meall Odhar granite ; they decrease in number downwards." Sheets of fine-grained granite also occur within other Scottish Caledonian granite intrusions such as Morvern-Strontian, Foyers, Cairngorm, and Lochnagar. It seems likely that closer examination of some of the eastern Grampian granites may reveal similar structural relationships between the main granites and the fine-grained granites such as obtain at Barnesmore.

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MAP SHOWING GEOLOGICAL ENVIRONMENT OF THE BARNESMORE COMPLEX (B.C.)

GEOLOGICAL MAP OF THE

BARNESMORE GRANITE COMPLEX

COUNTY DONEGAL, IRELAND

Carboniferous, mostly conglomerates

PLUTONIC ROCKS.

- G3.b Porphyritic
- G3.a Evengrained
- } Aplogranite & granite of the sheet complex
- G2 The main granite
- G1 The Cronamuck granodiorite

Crystalline schists of Dalradian age

Agglomerate-filled vents

Granodiorite-porphyry bosses

Bodies of metasomatized granite

Dip of contacts ..... vertical

Dip of Dalradian schists

Faults { Fractures without proved displacement omitted

Roads and tracks

Contours, at intervals of 200 ft.

Dykes of the Caledonian and Tertiary swarms omitted.

1 ½ 0 1 2 Miles

1000 500 0 1000 2000 3000 4000 Yds.

1 0·5 0 1 2 3 4 Km.

BASED ON THE ORDNANCE SURVEY BY PERMISSION OF THE MINISTER FOR FINANCE.